National Aeronautics and
Space Administration

Educational Product	
Educators & Students	Grades 3–12

EB-2001-12-020-JPL

Educational Brief

CASSINI SCIENCE INVESTIGATION

Waves

Objective

To demonstrate traveling, standing, transverse, and longitudinal waves.

Time Required: 1 hour

Saturn System Analogy: Many of Cassini's instruments collect transverse electromagnetic waves to learn about the Saturn system.

The cameras, spectrometers, radar, and radio receivers all provide information about Saturn and its rings, moons, and magnetosphere. The Huygens probe carries a microphone that will detect longitudinal pressure waves — sound — in the atmosphere of Titan.

Keywords: Amplitude, Earthquake Waves, Electromagnetic Waves, Frequency, Longitudinal, Node, P Waves, Period, S Waves, Sound Waves, Standing Waves, Transverse, Traveling Waves, Wavelength, Waves

MATERIALS

- Coiled spring toy (Slinky® or equivalent)
- Fixed attachment point for the spring

Discussion

Simple, *transverse* waves (Figures 1a, 1b) travel through many different media. Examples include water waves, S-type earthquake waves, and all electromagnetic waves, from radio signals through light to x-rays and gamma rays. Similarly, *longitudinal* waves (Figure 2) are common, from P-type earthquake waves to the sound waves we detect with our ears. These two types of waves can be easily demonstrated with a Slinky® or equivalent coiled spring toy.

Transverse and longitudinal waves can both be observed as *traveling waves* (Figures 1a, 1b, 2) and as *standing waves* (Figure 3). A traveling wave moves along the medium, carrying energy from the origin outward. A standing wave is confined, and must have a precise relationship between its characteristic size (called its wavelength, the distance from peak to peak or valley to valley) and the size of its confining volume. Specifically, a standing wave must have an integral number (1, 2, 3, etc.) of 1/2-wavelengths in the confinement zone. A standing wave can be considered a collection of traveling waves that, together, sum up so that there are nodes (positions of no wave motion) at the ends of the confinement zone, possibly with additional nodes between the ends.

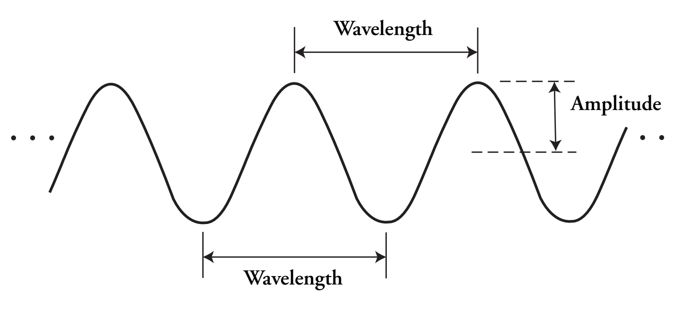

Figure 1a. A transverse wave (sinusoid, traveling, like swells at sea).

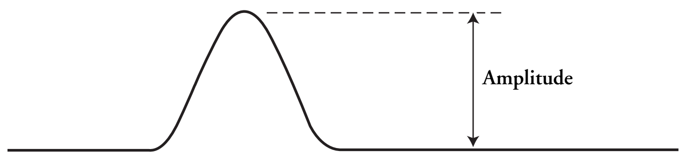

Figure 1b. A transverse wave (randomly shaped pulse, traveling).

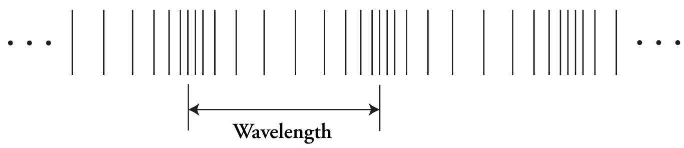

Figure 2. A longitudinal wave.

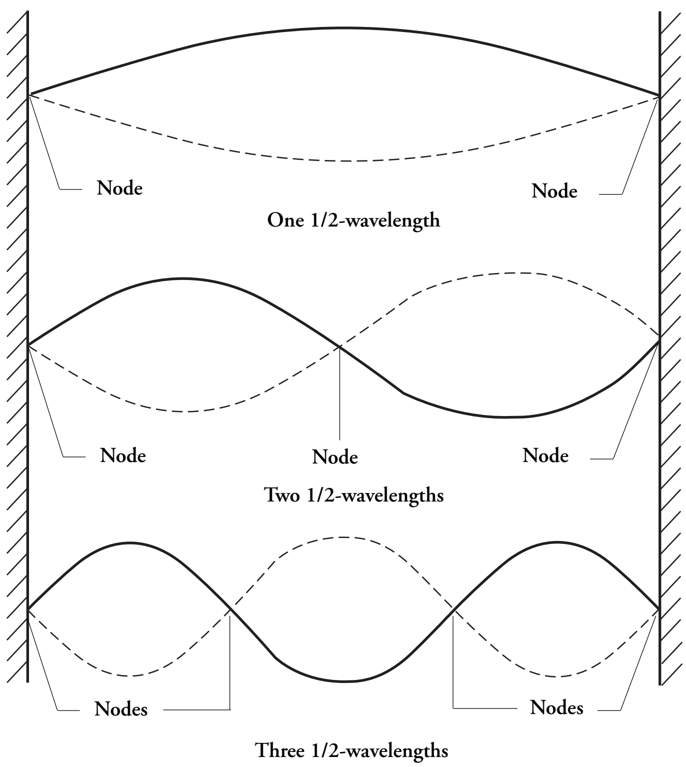

Figure 3. Standing transverse waves. Longitudinal waves may also be standing, but are difficult to illustrate.

Setup

Attach one end of the spring to a file cabinet, bookshelf, or other solid, fixed piece of furniture or the wall of the room. The end should not be free to move when attached, and should not come loose when the spring is shaken violently. A student can hold the "fixed" end, but must hold it tightly and in one position.

Procedure

Extend the spring across the room. Once it has settled, generate a traveling transverse wave by using a finger to make a quick pull and release in a vertical orientation. Try this several times, observing the reflection of the wave after it reaches the fixed end of the spring.

When the spring is again quiet, generate a traveling longitudinal wave by compressing a group of coils (totaling about 1 centimeter thick) towards yourself and then releasing the group. A compression/rarefaction combination will travel along the spring, and may reflect if the initial wave is strong enough. Repeat this several times. Is there a difference in wave speed for transverse and longitudinal waves? (The answer for P and S earthquake waves is yes.)

Now generate a standing wave. Using your arm, move the end of the spring up and down at a slow rate. Find the frequency necessary to get a single U-shape (transforming to an inverted U) of the spring between the moving end and the fixed end. When the shape is found, only small-amplitude arm motions are necessary to maintain it, which has a wavelength that is twice the length of the extended spring. This can be interpreted as the wave and its reflection exactly canceling out their respective motions at the fixed end and at your hand. Points where there is zero motion are called nodes.

Increase your arm-waving frequency. The spring's shape is disrupted, and waves and reflections interfere with each other and make chaotic spring motion until the correct frequency (twice the first one) is found. This new frequency permits a U/inverted U pair to form in the spring with one node in between. Now one wavelength is equal to the distance from your hand to the fixed end. Try higher frequency arm-waving to put 1.5 wavelengths (three U's, separated by two nodes + the two ends) and 2 wavelengths (four U's, separated by 3 nodes + the two ends) along the spring. Because of the nature of spring dynamics, it may be necessary to increase or decrease the distance between the ends of the spring to get more half-wavelengths excited.

How are wavelength and frequency related? The answer is inversely: shorter wavelengths have higher frequencies.

Extension

The standing waves in the demonstration were made by shaking the spring vertically, yielding waves with vertical polarization. Similarly, waves can be made by shaking the spring horizontally (harder for students to see from their seats).

If the spring is shaken with a circular arm motion (easier than maintaining pure vertical motion), the U-shape also follows a circular path (like a jump rope). This is circular polarization. But if one looks along the length of the spring and observes only vertical or horizontal motion (a long, thin rectangle cut into cardboard will make this easier to see), one can observe that the circular motion resolves into an equal combination of vertical and horizontal polarizations. These are analogs to polarization observed in electromagnetic waves that have practical applications in daily life, such as in glare-reduction sunglasses, and in spaceflight for communications to/from spacecraft.

Science Standards

A visit to the URL http://www.mcrel.org yielded the following standards and included benchmarks that may be applicable to this activity.

10. Understands forces and motions.

LEVEL 1 (GRADES K–2)

Knows that things move in many different ways (e.g., straight line, zigzag, vibration, circular motion).

LEVEL 3 (GRADES 6–8)

Knows that vibrations (e.g., sounds, earthquakes) move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source.

12. Understands the nature of scientific inquiry.

LEVEL 1 (GRADES K–2)

Knows that learning can come from careful observations and simple experiments.

LEVEL 2 (GRADES 3–5)

Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions).

Teachers — Please take a moment to evaluate this product at http://ehb2.gsfc.nasa.gov/edcats/educational_brief. *Your evaluation and suggestions are vital to continually improving NASA educational materials. Thank you.*

Student Worksheet — Waves

Procedure

Observe the different waves generated by your teacher with the spring toy.

List waves you can observe that are transverse waves.

List waves you can observe that are longitudinal waves.

What type(s) of wave(s) do earthquakes generate? There is a way to estimate an earthquake's distance from the arrival times of its waves. What are typical wave speeds that permit this?

What is polarization? In what common product is it used? How does it work and what are the results?

In what room of your home is it easy to demonstrate standing sound waves? (Hint: Some people like to sing there.)